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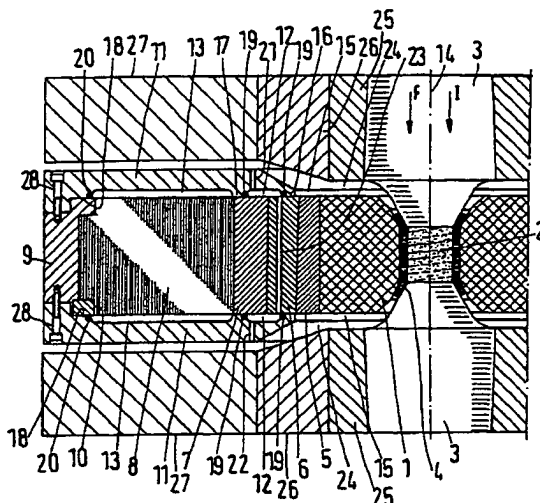
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(54) Title: HIGH-PRESSURE TOOL



(57) Abstract: In a high pressure tool with a die (1) of high pressure resistant material, particularly sintered hardmetal, which surrounds a hollow working space and is surrounded by an armouring (6, 7, 8) with at least one prestressing ring (6), the armouring (6 to 8) again is fixedly surrounded by an outer ring (9). To avoid a plasticizing of the material of the die (1) at high temperatures and very high pressure, occurring, for example, in connection with the production of synthetic diamonds in the tool, though maintaining a small overall height of the high pressure tool, it is ensured that at least on one end face of the armouring (6 to 8) a cover (11) is adjointly fixed, which cover (11) limits, close to the die, a first cooling channel (12) surrounding the axis (14) of the die (1) and having a hole (15) coaxial with the die (1), the diameter of the hole corresponding at least to the inner diameter of the hollow working space.

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High-pressure tool

5 The invention concerns a high pressure tool with a die of a high pressure resistant material, particularly sintered hardmetal, which limits a hollow working space and is surrounded by an armouring with at least one prestressing ring, the armouring being fixedly surrounded by an outer ring.

10

A high-pressure tool of this kind is known from DE 43 11 249 C2. Such a high-pressure tool is also used for the synthesis of diamonds or cubic boron nitride or the like. In this connection, the hollow working space is not merely exposed to pressures of 50 to 80 kBar by means of pressure pistons, but additionally, an electrical heating leads to an operating temperature of more than 1200°C in the working space loaded by the high pressure. Even though an isolating material, for example, pyrophyllite or a material with similar properties, is arranged between the high pressure die and the workpiece surrounded by the die, the inside of the high pressure die may be exposed to a temperature of a few hundred degrees Centigrade. With a surface temperature of more than 250°C on the pressure loaded inside of the die combined with the high pressure of 50 to 80 kBar, a plasticizing of the die material, even when it consists of sintered hardmetal, cannot be prevented. The consequence of this is that each pressure cycle will cause an increase of the pressure loaded inner diameter of the die. In the end, this increase may cause damage to the die, for example in the shape of micro- or macro-cracks.

The plasticizing of the die material cannot be avoided through a pressure reduction, as a very high pressure is a substantial condition for a successful synthesis. The thermal load of the die, however, depends on the degree, to which the heat supplied to the hollow working space of the die can dissipate through the isolating material into the

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surrounding die or to a cooling system. Tests have shown that the degree of plasticizing of sintered hardmetal depends very strongly on the operating temperature, and even a slight reduction of the temperature may extend the life  
5 of the die, before its material tires noticeably.

The US patent 4,523,748 discloses the formation of cooling channels in the armouring around the pressure and temperature loaded die, and additionally in a plate bearing on one  
10 end face of the die and adopting the pressure exerted axially on the die by a pressure piston and in the annular chambers surrounding the pressure pistons at the end faces of the die, to improve the cooling effect. Pressure loaded parts of the high pressure tool should, however, be sub-  
15 stantially free of cooling channels, in order that a notch effect caused by the cooling channels can be avoided to the highest possible degree. If the pressure pistons are immediately surrounded by cooling channels, these contribute to an increase of the overall height of the high-pressure  
20 tool. Additionally, they prevent the arrangement of an armouring surrounding the pressure pistons.

The invention is based on the task of providing a high pressure tool as mentioned in the introduction, which has a  
25 small overall height and a high cooling effect, and thus an increased protection against a plasticizing of the die material.

According to the invention, this task is solved in that at  
30 least on one end face of the armouring a cover is adjointly fixed, which cover limits, close to the die, a first cooling channel surrounding the axis of the die, and has a hole coaxial with the die, the diameter of the hole corresponding at least to the inner diameter of the hollow work-  
35 ing space.

A cover of this kind can be very thin, resulting in a small overall height in relation to the diameter of the high

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pressure tool, though ensuring a sufficient cooling of the die in most applications, without risking that the material of the die gets plastic.

- 5 Preferably, it is ensured that the cover bears axially on the armouring, close to a radial inner edge of the armouring, and that it is fixed with its radial outer edge to the outer ring, the cover being bent between its inner edge and its outer edge. In this way, the cover is pressed firmly on  
10 to armouring close to its inner edge, so that here a close and tight contact occurs between cover and armouring. Thus, a reliable sealing of the cooling channel is obtained, without a further weakening of the armouring caused by form-fitting fixing means, like for example thread bores,  
15 in the area being loaded by the highest radial pressure.

It is particularly advantageous that the first cooling channel is limited by a radial inner first annular bulge, and by a second annular bulge surrounding the first annular  
20 bulge, both bulges being arranged on the axial inside of the cover. Thus, the pressure force in the radial inner area of the cover, between the cover and the armouring, caused by the bolting of the cover, will be distributed on the two annular bulges, the second annular bulge acting as  
25 pivoting point, and the first annular bulge relieving somewhat during the fixing of the screwed connection, which again displaces the pressure force further radially outwards. A corresponding dimensioning of the distances between the annular bulges and their axial height permits the  
30 selection of the pressure forces between the annular bulges and the armouring so that they are substantially equal, thus securely sealing the cooling channel arranged between them against an escape of the cooling fluid.

- 35 Further, it is possible that the second annular bulge is surrounded by a third, radial outer annular bulge on the inside of the cover, the second and third annular bulges

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limiting a second cooling channel. This embodiment causes an even more effective cooling of the die.

When the first and the second annular bulges bear on one  
5 end face of the armouring and the third bulge bears on the  
outer ring, the armouring at the same time forms a limita-  
tion of the cooling channels, the armouring thus having  
immediate contact with the cooling fluid, preferably water,  
so that the heat from the die is dissipated via the armour-  
10 ing direct into the cooling fluid. At the same time, it is  
possible to make the cover very thin and correspondingly  
flexible, though maintaining a small overall height of the  
high-pressure tool.

15 Alternatively, it is, however, also possible that the cool-  
ing channel or channels is/are closed in the direction of  
the armouring by a heat conducting, membrane-like, thin  
plate being part of the cover. Such a thin plate only has a  
slight influence on the heat dissipation and the overall  
20 height. When it is correspondingly corrosion-proof, it  
protects the armouring against a corrosion caused by the  
cooling fluid.

Thus, it may be provided that the inner edge section of the  
25 cover has a reduced thickness in relation to the rest of  
the cover, particularly that it is bevelled in the direc-  
tion of the inner edge of the cover. This enables the main-  
taining of a small overall height with a correspondingly  
small distance between the covers and the armourings sur-  
30 rounding the pressure pistons, an increased axial length of  
these armourings in the area of the holes in the covers  
being possible, so that during the approach of the pressure  
piston to the workpiece, the armourings can penetrate into  
these holes.

35

The armouring of the die can be made so as to have a wind-  
ing of steel band around the prestressing ring or rings.

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This winding ensures a particularly firm radial support of the prestressing ring or rings.

When at the other end face of the armouring of the die a  
5 similar cover is arranged, and the cooling channels of both covers are connected by at least one cooling channel penetrating the armouring near the die, one cover having an inlet bore, the other cover having an outlet bore for a cooling fluid, the cooling fluid can flow in through one  
10 cover and flow out through the other, thus also dissipating heat from the inside of the armouring.

It is particularly advantageous that in the modified state the or each cover in side view has approximately the shape  
15 of a flat dish. When fixing a cover with this shape, the cover initially only bears on the armouring near the die with its radial inner projecting area, and can thus, through screw fitting of its radial outer edge area with the outer ring in a simple way be bent between its inner  
20 edge and its outer edge to bearing on the armouring, thus being prestressed in such a way that its radial inner edge area bears very firmly and tightly on the armouring.

Further, it is possible that at least the first cooling  
25 channel contains a cooling line bearing on the cover and on the armouring.

In the following, the invention and its embodiments are described in detail on the basis of the enclosed drawings  
30 of a preferred embodiment. The drawings show:

Fig. 1 a part of an axial section through an embodiment of a high pressure tool according to the invention

35 Fig. 2 a part of the axial section of the embodiment according to Fig. 1, however, without pressure pistons and their armourings, and in a state, in which one cover, bearing on a die armouring front

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5 face of the high pressure tool, and serving as a limitation of cooling channels, is only partly fixed by means of a screw connection, a corresponding cover, however, being completely fixed on the lower front face of the armouring

- Fig. 3 the same section as in Fig. 2, however, in a state, in which both covers of the armouring are fixed
- 10 Fig. 4 a section of the embodiment of the armouring according to the invention, to illustrate a potential axial relative displacement of parts of the armouring
- 15 Fig. 5 a diagram illustrating the dependence of pressure forces of the cover on the armouring when fixing the cover
- 20 Fig. 6 a diagram illustrating the pressure forces of the covers on the armouring in dependence of a cooling fluid pressure acting between the covers and the armouring
- 25 Fig. 7 the dependence of the pressure forces of the cover on a relative axial displacement of parts of the armouring
- 30 Fig. 8 a modified version of the embodiment according to Figs. 1 to 7.

According to Fig. 1, the embodiment of the high-pressure tool shown comprises a die 1 made of high pressure resistant material, here sintered hardmetal, alternatively also  
35 ceramic or steel. In the die 1 is arranged a workpiece in the shape of a block 2 consisting of, among other things, graphite, upon which counteracting pressure pistons 3 are acting with so high forces  $F$ , for the purpose of producing

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synthetic diamonds, that the block 2 is exposed to a pressure in the range from about 50 to 80 kBar. At the same time, the block 2 is heated by a current I of about 1500 A, which is led through the pressure pistons and the block 2, to ensure that, additionally to the heating caused by the compression pressure, the block 2 is heated to about 1200 to 1400°C. Between the die 1 and the block 2 a bush 4 of a thermally isolating material, preferably pyrophyllite, is arranged to protect the die 1, for example of sintered hardmetal, from a plasticizing, which may occur in connection with the high pressure at surface temperatures exceeding 250°C. If it happens, the inner diameter of the die 1 increases, the die getting micro or macro cracks, or even breaking completely. To provide additional protection of the die 1, it is surrounded by an armouring, which comprises a bush 5 surrounding the die, a first prestressing ring 6 surrounding the bush 5, a second prestressing ring 7 surrounding the prestressing ring 6, a winding 8 of a steel band surrounding the prestressing ring 7 and an outer ring 9 surrounding the winding 8. The contact surfaces of the bush 5 and the prestressing ring 6 are conical. The bush 5 is shrunk onto the die 1, the prestressing ring 6 is shrunk onto the bush 5, and the prestressing ring 7 is shrunk onto the prestressing ring 6. The winding 8 wound tightly around the prestressing ring 7 causes an extension of the life of the prestressing rings 6 and 7. Additionally to the prestressing rings 6 and 7 shown, further prestressing rings may be provided, to ensure that the die 1 can resist the high radial pressure forces.

The winding 8 of steel band causes that, in comparison with an armouring, in which the winding 8 is replaced by an additional prestressing ring, the permissible force F of the pressure pistons 3 can be increased by 25 to 40%.

Together with a clamping ring 10, the outer ring 9 forms a housing. The clamping ring 10 ensures that the tool can be mounted.



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A cover 11 is fixed by means of screws to be closely adjacent to each end face of the armouring (6 to 8). Together with the armouring, each cover 11 limits a first cooling channel 12 and a second cooling channel 13, which concentrically surround the middle axis 14 of the die 1, the first cooling channel 12 lying close to the die 1. Additionally, each cover 11 has a hole 15 coaxial with the die 1, the diameter of the hole being at least equal to the diameter of the hollow working space. In the present case, the inner diameter of the holes 15 is somewhat larger than the inner diameter of the prestressing ring 6. In this connection, each cover 11 bears firmly with the axial inner surface of a radial inner annular bulge 16 on one end face of the prestressing ring 6, with an axial inner surface of a second annular bulge 17 on an end face of the prestressing ring 7 and with an axial inner surface of a third annular bulge 18 on an axial outer end face of the outer ring 9 or the clamping ring 10, respectively. Each of the annular bulges 16 and 17 hereby limits the side of one of the first cooling channels 12, whereas each of the annular bulges 17 and 18 limits the side of one of the second cooling channels 13. Further, sealing rings 19 and sealing rings 20 seal the cooling channels 12 and 13, respectively, towards the armouring. One of the covers 11 is supplied with inlet and outlet bores 21 and the other cover 11 with inlet and outlet bores 22 for a cooling fluid, here water. Further, the cooling channels 12 can be connected via at least one cooling channel 23, which penetrates the armouring, here the prestressing ring 6 being closest to the die 1, so that the cooling fluid also flows through the armouring close to the die 1.

Each of the cooling channels 13, on the other hand, has not shown inlet and outlet bores for the cooling fluid. The cooling fluid flow can be controlled by form elements, which are either incorporated, screwed or welded on.

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The covers 11 have a relatively small thickness, the thickness of the inner edge section 24 being smaller than that of the remaining part of the cover, particularly decreasing towards the inner edge of the cover 11, the inner edge section 24 being bevelled.

Each of the pressure pistons 3 is also surrounded by an armouring, which consist of rings 25, 26 and 27 surrounding each other in a prestressed way, in a manner similar to the armouring of the die 1. The axial height of this armouring (25, 26, 27) increases on its axial inner side over the edge section 24 of the covers 11 to the centre of the holes 15, so that, with a sufficient stability of this armouring, only a small gap has to be provided between the armouring and the respective cover 11, which, in connection with the small thickness or height of the covers 11 contributes to a small overall height of the high pressure tool.

Each cover 11 bears near its radial inner edge or hole 15, respectively, axially on the armouring of the die 1, and is fixed by means of screws 28 with its radial outer edge on the outer ring 9, the cover 11 being bent between its inner edge and its outer edge.

Due to the bending, the covers 11 are prestressed against the armouring of the die 1.

By means of Fig. 2, the method of obtaining the prestressing is explained in the following.

In Fig. 2 the lower cover 11 is shown in the prestressed state, the upper cover 11, however, is not yet prestressed. In the unstressed or unbended state, respectively, each cover 11 has, in a side view, approximately the shape of a flat dish, its convex middle part, which is provided with the hole 15, facing the armouring of the die 1. When tightening the screws 28, initially only the radial inner annular bulge 16 is supported on the end face of the prestress-

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ing ring 6, until the cover 11 is bent so much between its radial inner and its radial outer edge, that eventually the second annular bulge 17 bears on the end face of the prestressing ring 7, and finally the third annular bulge 18 bears on the end face of the outer ring 9 or the clamping ring 10, respectively.

Figs. 3 and 5 show that while the radial outer edge of the cover is displaced by the distance X by the bending of the cover, each cover 11 with its first annular bulge 16 acts upon the prestressing ring 6 with an approximately linearly increasing force  $F_1$ , until also the second annular bulge 17 comes to bear on the end face of the prestressing ring 7, thus acting upon the second prestressing ring 7 with an approximately linearly increasing force  $F_2$ , the force  $F_1$  then decreasing to approximately the same extent as the increase of the force  $F_2$ , because of a pivoting of the cover 11 around the second annular bulge 17. The tightening force is finally selected so that the forces  $F_1$  and  $F_2$  are at least approximately equal, at least within the operation area surrounded by a circle in Fig. 5. In this area, the annular bulges 16, 17 and 18 bearing on the end faces, ensure a substantially sufficient sealing of the cooling channels 12, 13 up to relatively high cooling fluid pressures, without the cooling fluid entering the hot pressure area of the die 1, where it would expand (evaporate) explosively. An even better sealing for even higher cooling fluid pressures is reached by means of the sealing rings 19 and 20.

The diagram according to Fig. 6 shows how the forces  $F_1$  and  $F_2$  behave in connection with increasing fluid pressure  $P_w$  (see also Fig. 3), the surrounded area of the course of the forces  $F_1$  and  $F_2$  according to Fig. 6 showing the normal operating area. In this connection, the dimensioning and shaping of the cross section of the covers 11 should provide for the contact forces  $F_1$  and  $F_2$  to be so large that even a cooling fluid pressure  $P_w$  exceeding by far the nor-

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mal pressure does not jeopardize the absolute tightness of the cooling channels.

5 The very high radial forces acting in the high-pressure tool may cause small relative displacements in the axial direction between the individual rings. Such an axial displacement  $Z$  between the prestressing rings 6 and 7 is shown in Fig. 4.

10 A displacement  $Z$  amounting to a few hundredth millimetres is normally permissible for a substantially troublefree functioning of the high-pressure tool, and the prestressed covers 11 should be dimensioned so that they adopt such a displacement without problems.

15 With the displacement  $Z$  shown in Fig. 4, the contact force  $F_2$  at the upper cover 11 and the contact force  $F_1$  at the lower cover 11 decrease, which could render the cooling channels 12 leaky.

20 The diagram in Fig. 7 shows how the original forces  $F_1$  and  $F_2$  change in dependence of a relative displacement  $Z$ . Assuming that the nominal value of the cooling fluid pressure appears at a displacement of  $Z = 0$ , the forces  $F_1$  and  $F_2$   
25 have the same size.

A modification of the embodiment shown may comprise that cooling channels 12 and 13, made as grooves in the covers 11, are covered and tightly closed by means of a heat conducting membrane-like plate in each cover 11, the dish-like  
30 shape of the cover 11 in the side view remaining unchanged. Also here, the described kind of fixing and bending the covers, including their cover plates, ensures a high contact pressure and a good heat conduction via the armouring  
35 of the die 1 through the cover plate to the cooling fluid.

The membrane-like cover plates may have different functions. Thus, they do not only serve as heat conductors, but

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also as corrosion protection. Depending on their function, the plates can have a thickness ranging from a few hundredth of a millimetre (in the shape of a foil) up to several millimetres.

5

A modification of the embodiment shown is shown in section in Fig. 8. It may provide that at least in the radial inner cooling channel 12 of at least one cover 11 an annular cooling line 29, particularly a cooling hose, of flexible, heat conducting material, for example elastomer or rubber is inserted, without causing a substantial change to the sectional shape and embodiment of the cover 11. Merely the sealing rings 19 and the grooves adopting them are avoided.

15 Also with this embodiment, the described kind of fixing and bending ensures a high contact pressure, a large share of the surface of the inserted cooling line being in touch with the armouring, thus ensuring a good heat dissipation. Important in this connection is a contact pressure, originating from the bending of the cover 11, between the cover 11 and the cooling line 29, to prevent the fluid pressure from bulging the cooling line 29, thus decreasing the heat conducting contact area between the cooling line and the armouring.

25

This embodiment ensures a high degree of tightness, so that the cooling fluid cannot escape. This permits the use of coolants, which require absolute tightness with regard to safety, corrosion or the like. Additionally, this embodiment is substantially insensitive towards the relative displacements of various annular elements in the armouring described above.

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Patent Claims

1. High pressure tool with a die (1) of a high pressure  
5 resistant material, particularly sintered hardmetal,  
which limits a hollow working space and is surrounded  
by an armouring (6, 7, 8) with at least one prestress-  
ing ring (6), the armouring (6 to 8) being fixedly sur-  
rounded by an outer ring (9), **characterised in that at**  
10 **least on one end face of the armouring (6 to 8) a cover**  
**(11) is adjointly fixed, which cover (11) limits,**  
close to the die, a first cooling channel (12) sur-  
rounding the axis (14) of the die (1), and has a hole  
(15) coaxial with the die (1), the diameter of the hole  
15 corresponding at least to the inner diameter of the  
hollow working space.
2. High pressure tool according to claim 1, **characterised**  
**in that the cover (11) bears axially on the armouring**  
20 **(6 to 8), close to a radial inner edge of the armour-**  
**ing, and that it is fixed with its radial outer edge to**  
the outer ring (9), the cover (11) being bent between  
its inner edge and its outer edge.
- 25 3. High pressure tool according to claim 2, **characterised**  
**in that the first cooling channel (12) is limited by a**  
radial inner first annular bulge (16), and by a second  
annular bulge (17) surrounding the first annular bulge,  
both bulges being arranged on the axial inside of the  
30 cover (11).
4. High pressure tool according to claim 3, **characterised**  
**in that the second annular bulge (17) is surrounded by**  
a third, radial outer annular bulge (18) on the inside  
35 of the cover (11), the second and third annular bulges  
(17, 18) limiting a second cooling channel (13).

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5. High pressure tool according to claim 4, **characterised** in that the first and the second annular bulges (16, 17) bear on one end face of the armouring (6 to 8) and the third bulge (18) bears on the outer ring (9).
6. High pressure tool according to claim 4, **characterised** in that the cooling channel or channels (12; 13) is/are closed in the direction of the armouring (6 to 8) by a heat conducting, membrane-like, thin plate being part of the cover.
7. High pressure tool according to claim 6, **characterised** in that the plate is corrosion proof.
8. High-pressure tool according to one of the claims 1 to 7, **characterised** in that the inner edge section (24) of the cover (11) has a reduced thickness in relation to the rest of the cover (11), particularly that it is bevelled in the direction of the inner edge of the cover (11).
9. High pressure tool according to one of the claims 1 to 8, **characterised** in that the armouring (6 to 8) of the die (1) has a winding (8) of steel band around the prestressing ring (6) or rings (6, 7).
10. High pressure tool according to one of the claims 1 to 9, **characterised** in that at the other end face of the armouring (6 to 8) of the die (1) a similar cover (11) is arranged according to one of the claims 1 to 9, and the cooling channels (12, 13) of both covers (11) are connected by at least one cooling channel (23) penetrating the armouring (6 to 8) near the die (1), one cover (11) having an inlet bore (21), the other cover (11) having an outlet bore (22) for a cooling fluid.
11. High pressure tool according to one of the claims 1 to 9, **characterised** in that at least the first cooling

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channel (12) contains a cooling line (29) bearing on the cover (11) and on the armouring (6 to 8).

- 5      12. High-pressure tool according to one of the claims 1 to 11, **characterised in** that in the unbended shape the cover or covers (11) in side view have substantially the shape of a flat dish.



Fig.1

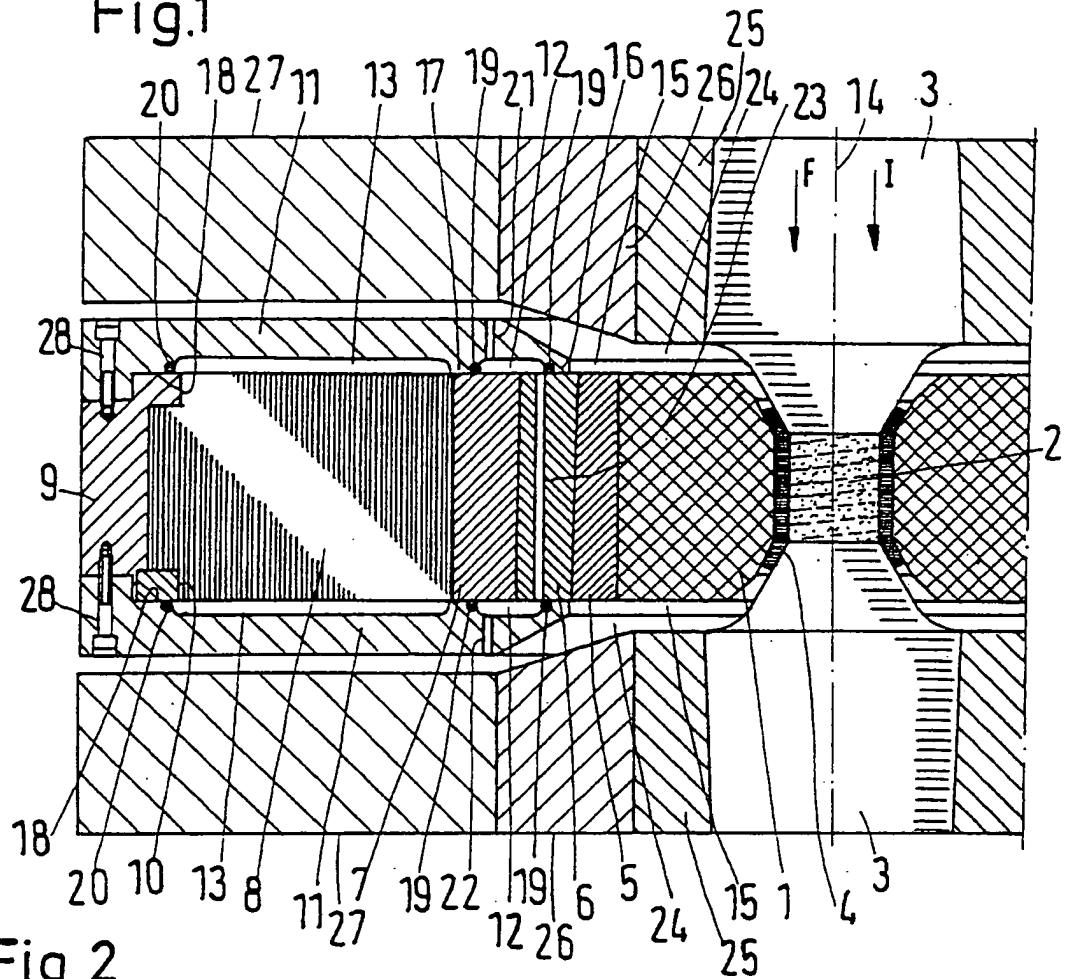
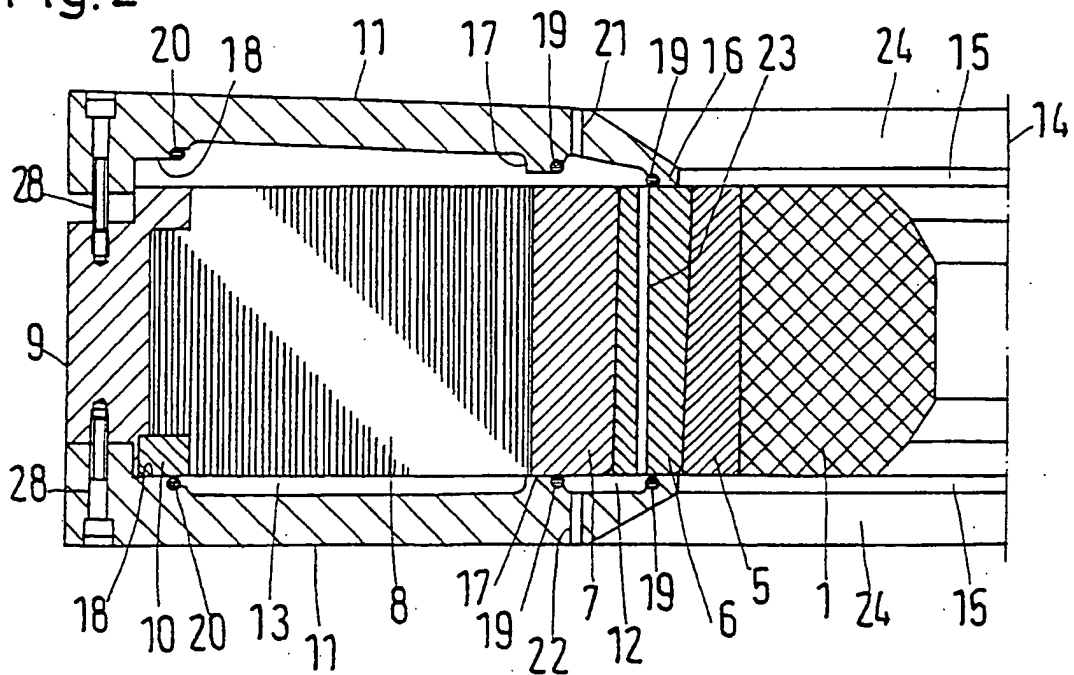


Fig.2





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Fig.5

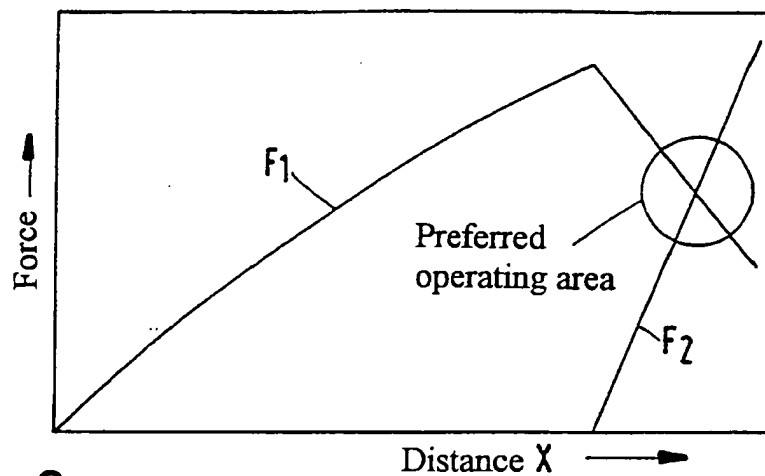


Fig.6

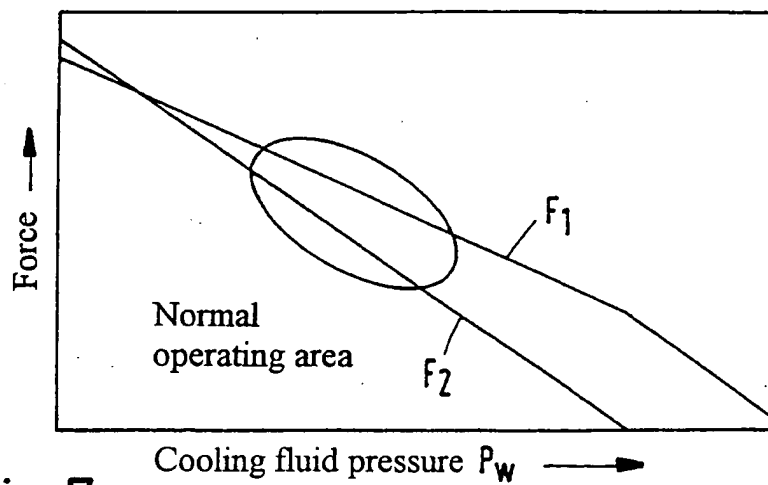
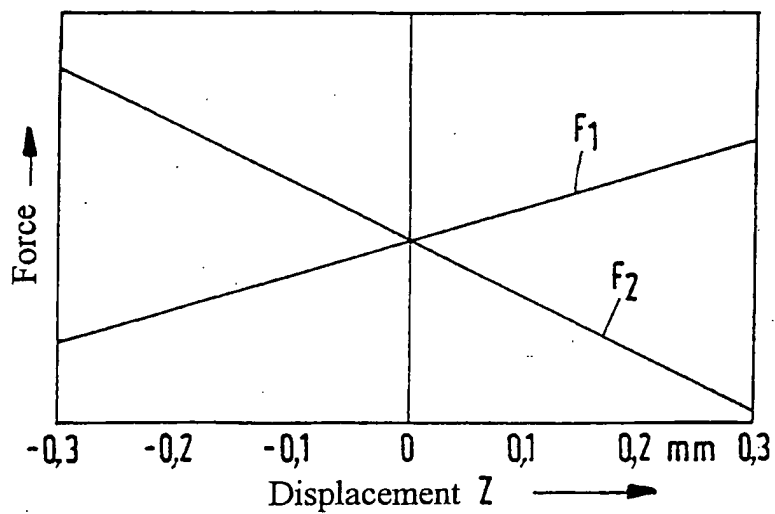


Fig.7



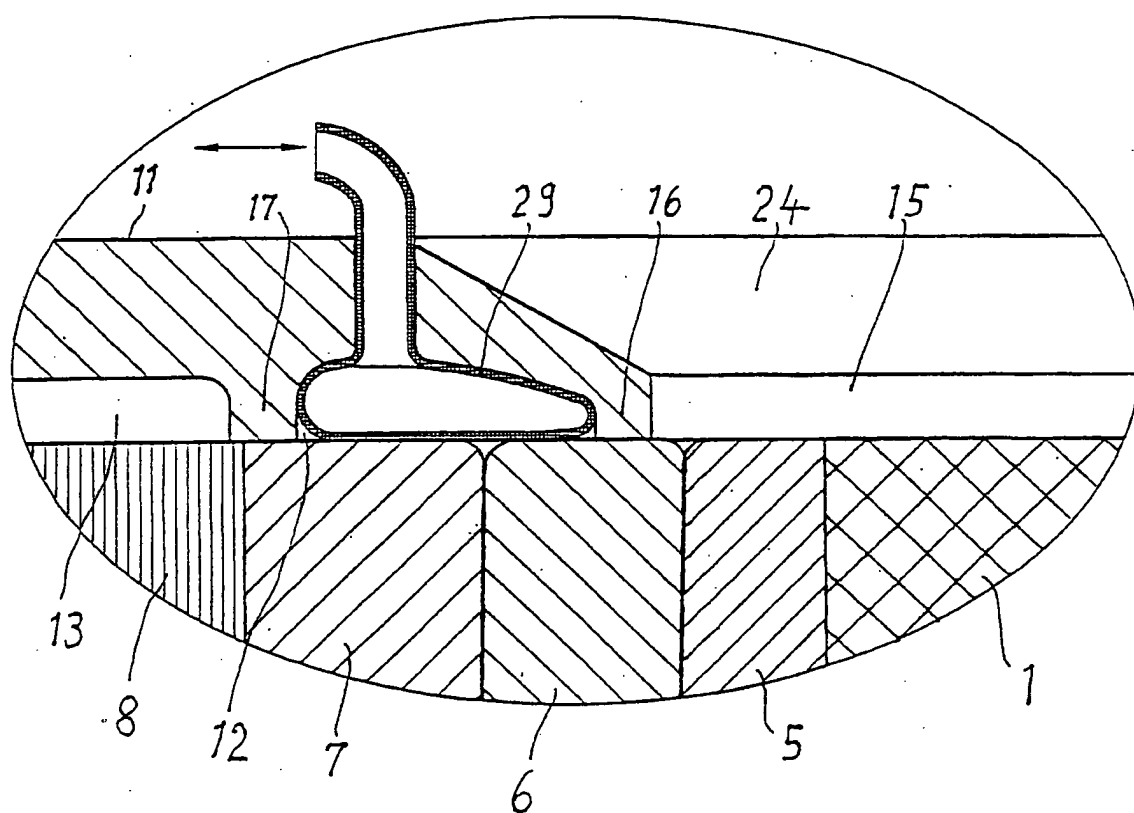


Fig.8

## INTERNATIONAL SEARCH REPORT

International Application No

PCT/DK 00/00638

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 B01J3/06 B21C25/02

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 B01J B21C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

WPI Data, PAJ, EPO-Internal

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category * | Citation of document, with indication, where appropriate, of the relevant passages                               | Relevant to claim No. |
|------------|--|-----------------------|
| A          | W0 94 22607 A (DANFOSS AS)<br>13 October 1994 (1994-10-13)<br>page 1, line 1 - line 21; claims 1-11<br>abstract  | 1-12                  |
| A          | US 4 523 748 A (LATTER RICHARD)<br>18 June 1985 (1985-06-18)<br>column 6, line 5 - line 53; figure 3<br>abstract | 1-12                  |
| A          | US 5 019 114 A (GRONBAEK JENS)<br>28 May 1991 (1991-05-28)<br>abstract   | 1,2                   |
|            | ---<br>-/--  |                       |

☒ Further documents are listed in the continuation of box C.☒ Patent family members are listed in annex.

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23 March 2001

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# INTERNATIONAL SEARCH REPORT

International Application No

PCT/UK 00/00638

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